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UPPER MINNEAPOLIS HARBOR DEVELOPMENT, MINNESOTA

by L. G. Yoder

WATERWAYS DIVISION

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UPPER MINNEAPOLIS HARBOR DEVELOPMENT, MINNESOTA

L. G. Yoder[1]

ABSTRACT

Progressive development of a navigable channel in the upper Mississippi River in the vicinity of St. Anthony Falls, Minnesota, resulted in a plan, authorized in 1930, for improvement to provide a minimum channel depth of nine feet. This improvement, now in process of construction, includes two locks, channel dredging, removal of an existing dam and construction of one new dam and minor improvements to an existing one. The work is complicated by unfavorable geology and by existing improvements which require close control of water levels between the two locks. The history of the development and the principal factors influencing design are described in detail.

Between St. Paul, Minnesota, and the lower end of the St. Paul District, at Guttenberg, Iowa, the Mississippi River meanders through a broad level valley which is from one-half mile to three miles wide. The broad plain consists of alluvial deposit laid down in the gorge which had been eroded in the sedimentary rocks of the region during the recession of the glaciers. The range from extreme low water to extreme recorded high water varies from about 18 to 26 feet.

Since the earliest settlement of the Midwest, the Mississippi River has served as a means of transportation and, as development of this region progressed, the river became increasingly important as an artery of commerce. With the growing demands of navigation, attempts were made to secure greater navigable depths by open river methods involving an extensive system of contraction works supplemented by a group of six headwater storage reservoirs to increase the discharge during low-flow periods. The eventual goal by such means was a dependable 6-foot depth in the river below St. Paul. However, with the low flows experienced, particularly in the upper end near the Twin Cities, this depth could not be obtained. This led to the authorization for construction of the locks and dams now known as locks and dams Nos. 1 and 2 at the Twin Cities and Hastings, respectively, toward the end of the 1920's. Recognizing the need for further increase in both navigable depths and dependability, Congress by the 1930 River and Harbor Act authorized the present 9-foot canalization project. In addition to the two locks and dams just mentioned, nine additional locks and dams were constructed in the St. Paul District downstream from lock and dam No. 2 during the 1930's. It may be noted that canalization by locks and dams was also effected during this period down the Mississippi River to Alton, Illinois, a short distance above the mouth of the Missouri River. This development provided a dependable

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9-foot channel up to the lower Northern Pacific Railway bridge in Minneapolis, which for several years has been known as the head of the 9-foot channel project. The existence of towns, railroads, and agricultural developments within the flood plain made it necessary to adopt comparatively low head locks and dams. The locks in the St. Paul District have heads ranging from 5.5 feet to 37.9 feet. The highest head, 37.9 feet, is at locks and dam No. 1. In the St. Paul District the locks below St. Paul are 110 feet by 600 feet in plan, but two smaller locks, each 56 feet by 400 feet, were built at dam No. 1. The generally smaller size of the river channel and its sharper curvature above St. Paul led to the assumption that the larger through-traffic tows would be disassembled at the docks in St. Paul, with movements through locks No. 1 generally comprising units of only one or two barges.

With the exception of the Twin City locks, navigation structures in this district are founded upon alluvial deposits. The alluvial fill of the valley is generally clean sand. There are also deposits of clay and silt that were laid down at times when the river was ponded by natural obstructions.

The standard design of locks for the Upper Mississippi River was established by the Corps of Engineers after careful study of practice in Europe and experience with existing structures in the United States. The newer practices in the design of locks are not the result of radical changes and discoveries but of a gradual evolution which is made possible by the availability and use of newer construction materials and methods, the study of lock and dam structures by means of hydraulic models, and the application of modern developments in foundation engineering.

As a general practice, lock walls are of mass concrete designed to be stable as gravity type walls, with all walls and other heavy elements built on piling. Concrete struts between walls assist in resisting lateral forces. The control sections of the 9-foot channel dams, with the exception of dam No. 1, are batteries of tainter and roller gates, the number being dependent upon hydraulic conditions at each location. In times of flood, all tainter and roller gates may be raised above flood level to pass flood flows with only a slight swell-head effect. Lock gates are of steel and in nearly all cases they are of the miter type.

Lock No. 2 in the St. Paul District is founded on timber piles driven into a sand layer which overlies a 60-foot-thick stratum of clay. In addition to settling caused by the consolidation of the clay, the lock wall rotated landward at the top causing some misalignment of the lower miter gate. This landward rotation occurred not only in spite of, but because of, the backfill behind the landwall. The condition was improved by the removal of a portion of the backfill. A second lock was constructed at this site some years later landward of the first lock. Monoliths supporting the upper and lower miter lock gates are supported on 132-foot steel "H" piling that penetrate the clay stratum. The backfill between the gate bays of the two locks was lowered to minimize the loading on the clay and the resultant effect of consolidation.

At the present time the St. Paul District, Corps of Engineers, is responsible for the design and construction of the St. Anthony Falls Project, commonly known as the "Upper Minneapolis Harbor Development."

Up to this time the City of Minneapolis has been able to develop only a small river terminal area in the vicinity of the Washington Avenue bridge, much too restricted to serve this large metropolitan center and the tributary area extending to the west. The idea of ascending the Falls of St. Anthony and reaching more suitable terminal sites above the Falls is hardly

a new conception. As early as 1870, Franklin Cook, a civil engineer employed by the Corps of Engineers, reported upon the feasibility of carrying transportation through the Falls by means of a system of locks. This idea has been kept alive through the years. Efforts by the City of Minneapolis resulted in authorization by Congress in 1937 of extension of the 9-foot channel project over St. Anthony Falls, a distance of 4.6 miles.

From an engineering standpoint, this undertaking is recognized as a complex and rather difficult problem. In order to fully appreciate this problem, it is necessary to go back into the past about 20,000 years when the Falls of St. Anthony, according to geologists, was situated in the vicinity of Fort Snelling, located approximately five and one-half miles downstream of the present Falls. The formation of the Falls at that time was brought about by conditions that still exist today. This entire area is underlain with a thin layer of Platteville limestone which rests on a rock formation known as St. Peter sandstone. The latter has been a boon to construction of tunnels and sewers in the Twin Cities area, but with respect to projects in the river, it is recognized as a very hazardous foundation material. It is a very soft, friable rock composed of quartz spheres of very uniform particle size, deposited in ages past, and contains little or no cementation. The grains of sand are bonded loosely together primarily as a result of the pressure from the rock and earth overburden. The sandstone is so soft that a stream of water directed upon it immediately causes it to disintegrate into a fine, white quartz sand. This characteristic made tunneling for various projects in this region extremely easy. For example, when the interceptor sewer for the Minneapolis-St. Paul Sanitary System was being constructed, in St. Paul particularly, the material could be virtually dissolved into a slurry of fine sand and pumped to the surface for disposal. When this St. Peter sandstone is encountered in the bed of a river, it is readily apparent that it must be handled cautiously. In its undisturbed state and as long as no water is moving across its surface, the material will carry almost unlimited loads; but unless it is confined and protected, structures built on it cannot be assured of a long, useful life.

The layer of harder, but fractured, limestone above the sandstone varies in thickness from about 25 feet near Fort Snelling to a feather edge in the vicinity of Nicollet Island just above the existing Falls. In the last 20,000 years, the river has flowed over this harder limestone; but in toppling over the edge of it, the water has disintegrated the underlying soft sandstone. The undercutting caused the limestone ledge to break off periodically and fall into the chasm. Thus the Falls receded upstream at an average rate of about 18 inches per year.

When the first settlers came to this region, the Falls had backed up nearly to its present position. As stated previously, the upper edge of the limestone cap disappears about 1,500 feet upstream; and if the recession had been permitted to continue, the Falls would have disappeared completely, leaving only a series of rapids.

The United States Army made the first use of the water power at St. Anthony Falls in a mill built for the purpose of grinding flour shortly after the founding of Fort Snelling in 1819. By about 1860, a number of diverting dams had been built and connected in various ways on the limestone cap at the Falls of St. Anthony to furnish water power for sawmills and flour mills in the vicinity. These dams prevented the undercutting of the sandstone, stabilized the limestone ledge rock, and preserved the Falls.

In the fall of 1868, an enterprising individual named Eastman started construction of a tunnel from the lower end of Hennepin Island and planned to

extend it upstream to the lower end of Nicollet Island for the purpose of additional water power development. On the 4th of October, 1869, when this excavation had reached a point near the lower end of Nicollet Island, the workmen were driven from the tunnel by a sudden entrance of a considerable volume of water. Fortunately, no one was drowned; but in a short time the tunnel, which was of modest size, was increased greatly by the erosive action of rapidly flowing water. In the next two or three years following this accident, attempts were made to plug the entrance to the tunnel which was found to be above the upstream edge of the limestone cap.

The first Army engineer officer to inspect the work at the Falls, Major General G. K. Warren, is generally designated as the first St. Paul District Engineer, serving in this position from 1866 to 1870.

Following his inspection of the difficulties at the Falls, General Warren assigned the immediate supervision of work to plug the tunnel to the civil engineer, Franklin Cook, who was referred to earlier. A cofferdam was built around the break to stop the flow, and earth materials were used to block the tunnel. But as Mr. Cook proceeded with the work, each time he seemed to be successful in plugging the tunnel another break near the upstream edge of the limestone cap would occur. Finally, Mr. Cook recommended that a concrete dike be constructed beneath the limestone cap to provide an effective cutoff across the entire width of the river. This proposal was subsequently endorsed by other eminent engineers and committees appointed to preserve the Falls of St. Anthony. Ultimately, an appropriation was obtained from Congress; and this dike, 40 feet in height, was constructed beneath the limestone cap in the period between 1874 and 1876. The concrete dike effectively solved this problem at the Falls; and, needless to say, no more tunnels were constructed in the region, although there is on the record the fact that one additional attempt was made before it was stopped.

The Minneapolis Harbor Development project consists essentially of the extension of the existing 9-foot channel from its present limit at the Northern Pacific bridge to a point near the north limits of the City of Minneapolis, the extension covering a distance of about 4.6 miles by river. The entire scope of the project showing the various features can be noted on Figure 1. A pictorial presentation of the lower lock and dam along with the upper lock through the existing dam showing the relation to existing structures can be noted on Figure 2. The estimated Federal cost of the Harbor Development is approximately $31,000,000. The total cost, including contributed funds plus land and damages and relocations by the City of Minneapolis, is estimated at approximately $34,000,000. The project includes extensive dredging in material varying from sand to ledge rock; construction of a lock and dam to replace the present lower dam; construction of a lock through the upper dam; protection of bridge piers; construction of guide walls and navigation aids; removal, extension, and alterations of various pipe crossings, cables, sewers, pump intakes, and other obstructions to navigation. In order to present the general features and details of the proposed project, the various units will be described beginning at the lower Northern Pacific bridge and proceeding upstream.

The first portion is referred to as lower dredging. It extends from the lower limit of the project to the proposed new lower lock and dam. It is a channel approximately 400 feet wide dredged to a depth of 10.0 feet below the lowest controlled pool of dam No. 1. The material is a heterogeneous mixture of sand, gravel, some clay, glacial boulders, broken-up limestone, limestone blocks and slabs and ledge St. Peter sandstone. The Northern

Pacific Railroad bridge and the Cedar Avenue bridge span the river in this reach. No alteration other than provision for guard fences around the center pier of each bridge is required.

The next unit is the lower lock and dam. The proposed structure is located downstream of the present lower dam and extends in a straight line across the river at right angles to the flow. The lock and dam was laid out to provide navigation access through the Minneapolis Western bridge and tie into the existing power house on the left bank. The lock, with a chamber 56 by 400 feet clear, has a normal lift of 25 feet. The upper gate bay for an auxiliary lock is provided so that a second lock can be built at a later date in the event increased navigation requirements dictate its need. The dam contains three tainter gates, each 56 feet long and 20.5 feet in height. Under normal river conditions these three tainter gates pass all flows. To assist in passing high flows, tainter gates are provided for the upstream service gates of both locks. During normal use of the lock, the tainter gate will submerge for passage of navigation into and out of the lock.

The work in the intermediate pool consists mostly of dredging a suitable approach channel between the upper and lower locks. The material to be excavated is substantially the same as that encountered in the lower pool area. In the early stages of planning, two railroad bridges and one highway bridge crossed the river in this reach. Subsequently, one railroad has been removed and the superstructure for the highway bridge dismantled. The other railroad bridge is a stone arch structure. One pier and two spans of this bridge will be replaced with a steel span in order to make room for the new channel. Field observations and hydraulic model investigations indicated that extremely hazardous navigation conditions could be expected in the intermediate pool unless corrective measures were provided. The location and alignment of the existing upper dam wasteways located on the left side of the river, aided by the skewed position of the piers of the stone arch railway bridge, direct the flow into the navigation channel causing a serious cross-current. To provide relief from this condition, a training wall was developed in the model investigations, which will extend from the downstream end of the upper lock river wall to a point approximately 1,100 feet downstream and will be slightly curved to deflect the river toward the lower dam. The present lower dam located in this reach of the river will be removed upon completion of the lower lock and dam.

The upper lock will be located immediately below the non-overflow section of the present upper dam on Upton Island. This lock has the same horizontal dimensions as the lower, but the lift at this site is 49 feet. Its purpose is to make possible the surmounting of the main Falls and the existing upper dam. The lock will not infringe on the spillway capacity of the dam, which is considered adequate. However, alterations of relatively minor nature will be required to bring the crest of the existing spillway to a uniform elevation to prevent drawdown of the upper pool to less than project depth. As at the lower lock, it is proposed that the upper lock gate be a submergible tainter gate to assist in passing unusually high flows and to pass debris and ice that may interfere with navigation in the long, narrow upper approach channel. The lower gate is to be the conventional mitering type.

The proposed work in the portion between the upper lock and the upstream limit of the project will be principally dredging and bridge alterations. The channel will be 150 feet wide with a turning basin approximately 500 feet wide and 1000 feet long located downstream from Lowry Avenue bridge. The material to be dredged in general consists of sand, gravel, clay, and boulders. In addition, ledge limestone will be encountered in the area between the upper

lock and Hennepin Avenue bridge. Seven bridges cross this reach of the river. Guide fence protection will be required at Hennepin Avenue bridge and Third Avenue bridge. The Great Northern bridge near the Union Station will be provided with a lift span. Broadway and Plymouth Avenue bridges and the Upper Northern Pacific Railway Company bridge must be raised to provide adequate vertical clearance. A new bridge is proposed at Lowry Avenue.

Much of the preliminary work on this project had been accomplished before the start of World War II. A complete topographical survey of the upper harbor had been made, and considerable number of borings had been taken. The Corps of Engineers arranged for a geological report on the foundation conditions at the lock sites and the dredging area, and this report was prepared by Dr. G. M. Schwartz of the University of Minnesota and present head of the U. S. Geological Survey for the State of Minnesota.

A thorough study of the hydraulic problems involved in the project was made in a hydraulic model simulating the river between the Hennepin Avenue bridge and the lower Northern Pacific Railway bridge. This model, built to a scale of one to fifty, was constructed at the University of Minnesota Hydraulic Laboratory. The following aspects of the project were investigated: the hydraulic feasibility of the project, the most desirable locations of the locks and dam, current conditions in the lock approaches and through the bridges, and the backwater caused by proposed structures. Model studies were also made on the spillway and submergible Tainter lock gates to determine the proper shape of crest, the sill profile, and length of apron for the lower dam. The details for the filling and emptying systems for the lower lock were developed in other models. Similar model tests for the upper lock will be required.

Due to the fact that the sandstone on which the structure must be built disintegrates readily when exposed to seepage or running water, and because gravity walls at the lower site would have reduced the critically needed spillway area, the dry dock type lock was adopted. The cross section of the lock is an integral structure. The lock floor is considered a beam on an elastic foundation, with the side walls designed as cantilevers. Barring cracks in the concrete, this type of construction will positively insure that no water can seep from the lock chamber to any point beneath the walls, and thus it is fairly certain that the walls cannot be undermined.

The present Lower Dam at St. Anthony Falls provides a head for water power development. Although shorter than the existing dam, the new lower dam will provide the same discharge capacity. No alterations to the upper dam will be necessary except to provide an opening for the lock structure and slight modifications to secure a uniform crest elevation. Extreme care will be taken not to disturb the concrete cutoff dike underneath the limestone ledge, which has been described earlier.

All gates, including the lock gates, are designed to pass flood flows. For this reason the gate at the upstream end of each lock is a Tainter gate. The auxiliary spillway capacity provided by the lock is required in the case of the lower dam, particularly because variations in the intermediate pool level must be restricted. Numerous facilities which line the banks would be damaged by a rise in pool level of only a few feet. On the other hand lowering of the pool would interfere with cooling water intake lines and draft tubes of power facilities. These restrictions also dictate some of the construction requirements. To be able to pass spring run-off, during the construction period, not more than about one-third of the river can be cut off. It was also necessary to accomplish the lower dredging as the first step of the program, in order to provide the necessary waterway area along the right bank opposite the first section of the cofferdam.

At this point it appears well to mention that Congress authorized the project with the provision that local interests bear the cost of necessary bridge modifications and adjustments to utility structures, and furnish free of cost to the United States all lands needed for the improvement. The City of Minneapolis assumed all the responsibility for the required local cooperation and, as a partial fulfillment of this responsibility, has deposited with the Government $1,100,000 to defray the cost of the required alterations to the railroad bridges and the utility structures. Thus, the Corps of Engineers now is directly responsible for making the alterations to railroad bridges and utility structures, while the City of Minneapolis has the responsibility of altering the city-owned bridges and facilities, and furnishing the lands required for the project. A portion of the work required on the railroad bridges and utility structures is to be accomplished by the Corps of Engineers, but the greater portion of it will be accomplished by the railroads, and paid for by the Government, using contributed funds.

The present plan is for the Government to contract with the railroads for the engineering work required on the railroad bridges. A contract was negotiated with the Great Northern Railway Company for the work on the Minneapolis Western bridge. The actual work was included in a contract for construction of the lower lock and dam. The bridge alterations covered in the contract consisted of the reconstruction of two piers adjacent to the proposed lower dam abutment and the encasing in concrete of seven other steel bents. However, high flows during the 1951 spring run-off caused considerable scour in the vicinity of several of the bridge piers, and a considerable portion of one of the main piers was undermined. The resulting unstable condition of the bridge led the Great Northern Railway to request modification of the contract and to arrange for dismantling the bridge. This was accomplished during the 1951-1952 winter season. The contract for the Lower Northern Pacific Railway Company bridge has been negotiated and a contract has been let for this work to be accomplished in the 1955 construction season.

Preliminary plans prepared by the Great Northern Railway have been reviewed by the District office for the work required in connection with the alterations of the Stone Arch bridge. Remodeling of the Stone Arch bridge will, in itself, be a considerable project. It will be necessary to accomplish this work under traffic, because it appears impossible to reroute the large number of trains of the various railroads which operate over this bridge. A feasible plan has been worked out and a contract will be negotiated with the Great Northern Railway when funds become available.

The Corps of Engineers is receiving the full cooperation of the City of Minneapolis, the railroads, power company, and other interests involved in the project. The city is proceeding with its work on the bridges in the upper pool area. New cylinder piers were constructed in 1949, to assist in supporting the Broadway and Plymouth Avenue bridges in their raised position. As of this date the Broadway Avenue bridge has been raised 19 feet and the Plymouth Avenue bridge 17 feet and both are open to traffic in their final positions. The Lowry Avenue bridge is low by 13-1/2 feet and the City of Minneapolis proposes to replace this bridge with a new structure that will provide adequate horizontal and vertical clearance. At the upper Northern Pacific Railroad bridge an additional vertical clearance of 15 feet is required. To provide adequate horizontal clearance it will be necessary to remove one pier in the proposed channel. Vertical clearance can be obtained, in part, by raising the structure, and, in part, by substituting a through truss for the channel span.

There are other utility problems, such as the water-cooling pumping plant for the Minneapolis Gas Company. A contract has been negotiated with this company to provide direct access to the city water main for the necessary cooling water, and for the elimination of the present facility.

In addition to the work to be accomplished by the city, the main work by non-Federal agencies is the reconstruction of the hydroelectric station by the St. Anthony Falls Water Power Company. An additional head of about four feet will become available at this site as a result of the dredging below the lower dam, accomplished by the Corps of Engineers. When construction of the new lower lock and dam has been completed, the existing lower dam will be removed by the power company.

In general, work on the various features of the project was planned to begin at the lower end and to proceed upstream.

The first stage of the lower dredging was accomplished in the latter part of 1948. A second contract for the dredging up to the site of the proposed new lower lock and dam was completed in December 1950. The material dredged was loaded on barges by floating power equipment and transported by water to a disposal area downstream. The total cost of the dredging under both contracts was approximately $800,000.

Bids were solicited for construction of the lower lock and dam in the spring of 1950, the contract for which amounted to approximately five and one-half million dollars. Construction was started on this contract in the summer of 1950. In order to carry out the provisions of the contract, cofferdamming of the river by several stages is required. Originally it was planned to perform the work in three cofferdams, extending over four construction seasons, but due to unanticipated foundation conditions, and unusual river conditions, it has been necessary to revise the plan to four cofferdams, and the work will extend over six construction seasons. Briefly stated, approximately two-thirds of the river must be clear to pass spring run-off, and one-third for summer, fall and winter flows. Stage I of the revised plan consists of constructing a cofferdam approximately one-third the width of the river from the left bank. Stages II and III inclose the proposed lock along the right bank. Stage IV cofferdam is a bulb type cofferdam constructed during low flow period extending off Stage III to inclose pier 3 and sills 2 and 3 of the dam.

Foundation conditions have presented the most difficult construction problems. The original borings indicated that the St. Peter formation was a homogenous material of uniform density. Excavation in the formation reveals horizontal seams 4 to 6 feet on centers. If these seams are exposed the sand is displaced and voids are created. Several means have been tried to prevent the opening up of such areas. The first measure was to encircle the work area with steel sheet piling. To perform this operation it was necessary to jet a trench to within about two feet of the total depth and to seat the piling in the undisturbed sandstone by driving. This method, although effective, did not cut off all of the flow. There was leakage through the interlocks, and some spreading or separating of the interlocks. In such cases additional sheets were placed to lap the openings, but this method did not eliminate the flows. It was difficult to obtain a true vertical trench by this jetting method, and, therefore, it was necessary to lap the piling at the closure location. In order to dry up certain areas it was necessary to resort to a well point system. This was especially effective in the deep key section along the non-overflow dam and the upstream face of the spillway. There were break-throughs, however, and when they occurred in the keyway area

it was necessary to backfill and seal off the void area, created by the flowing water, with chemical grout. Chemical grouting was also used to solidify the disturbed sand in the areas within the structure where the steel piling was jetted into the sandstone.

Highwater has also caused considerable trouble and delays. The adopted height of cofferdam was based on the high water data recorded since 1907. However higher flows than anticipated occurred and it was necessary to flood Stage I cofferdam on three occasions.

Some substitutions have been required due to difficulties in procuring materials, but in general, progress has been normal after the placing of the concrete in the foundation pours.

Revisions in the contract necessitated by unforeseen foundation difficulties and periods of high flows have increased the cost of the contract to approximately $7,800,000 delaying the scheduled completion date to February 1956.

Other main items of work are the upper lock and the Great Northern Stone Arch bridge. Since the upper lock is to be constructed on an island, some of the hydraulic considerations in the construction plan will be less serious than at the lower lock and dam. However, because of the high lift and the rock formation, difficult seepage conditions are anticipated. Although plans are not completed, it is estimated that it will require about four years to complete this item of the project.

A model study will be made to develop the hydraulic system for the upper lock. The structure will be similar to the lower lock, because it is to be built on the same type of material. The lower gates will be the conventional horizontally-framed miter gates, but the upper gate will be a submergible Tainter gate to assist in lock filling operations, and also to assist in the passing of ice and debris in the upper approach channel during periods of high water.

The design and construction program is dependent upon the availability of funds. At the present time all future work on design is deferred pending the result of an economic survey currently being made on the over-all feasibility of the project.

As previously noted, some of the items of work, such as the lower lock and dam, and the upper lock, will respectively require six and four years to construct. Certain other items of work, such as dredging of the intermediate pool area, can most economically be accomplished after completion of the lower lock and dam, which will permit the bringing in of floating equipment. In the upper pool the City of Minneapolis and the Government will require time to alter the highway and railroad bridges in order that dredges may pass through them in accomplishing the dredging in this area. As indicated, some of the remaining items of work will be carried on simultaneously, but even so, it is estimated that approximately eight years will be required to complete the project provided sufficient funds are appropriated to meet that schedule.

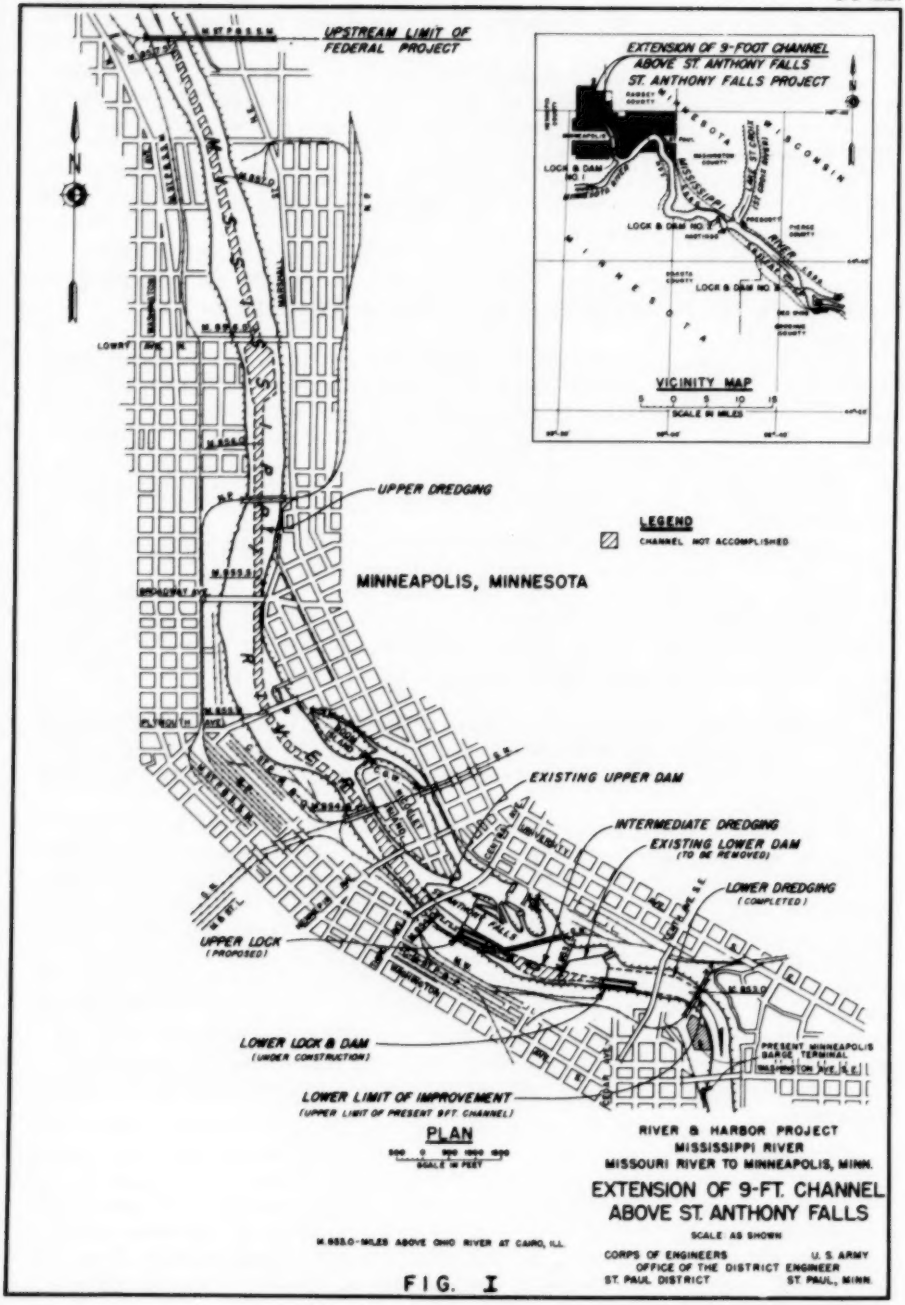
UPSTREAM LIMIT OF FEDERAL PROJECT
EXTENSION OF 9-FOOT CHANNEL ABOVE ST. ANTHONY FALLS
ST. ANTHONY FALLS PROJECT
VICINITY MAP
SCALE IN MILES
UPPER DREDGING
LEGEND
CHANNEL NOT ACCOMPLISHED
MINNEAPOLIS, MINNESOTA
EXISTING UPPER DAM
INTERMEDIATE DREDGING
EXISTING LOWER DAM
(TO BE REMOVED)
LOWER DREDGING
(COMPLETED)
UPPER LOCK
(PROPOSED)
LOWER LOCK & DAM
(UNDER CONSTRUCTION)
PRESENT MINNEAPOLIS BARGE TERMINAL
LOWER LIMIT OF IMPROVEMENT
(UPPER LIMIT OF PRESENT 9FT. CHANNEL)
PLAN
SCALE IN FEET
RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
MISSOURI RIVER TO MINNEAPOLIS, MINN.
EXTENSION OF 9-FT. CHANNEL
ABOVE ST. ANTHONY FALLS
SCALE AS SHOWN
M 853.0-MILES ABOVE OHIO RIVER AT CAIRO, ILL.
CORPS OF ENGINEERS U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT ST. PAUL, MINN.

FIG. I

MISSISSIPPI RIVER

MINNEAPOLIS, MINN.

ST. ANTHONY FALLS PROJECT

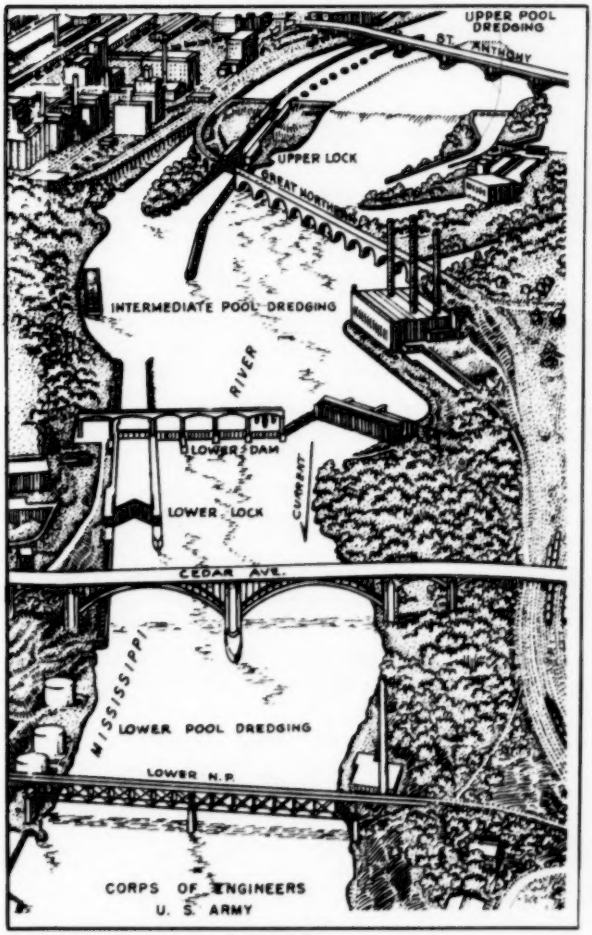

FIG. II

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SEPTEMBER: 484(ST), 485(ST), 486(ST), 487(CP)[c], 488(ST)[c], 489(HY), 490(HY), 491(HY)[c], 492(SA), 493(SA), 494(SA), 495(SA), 496(SA), 497(SA), 498(SA), 499(HW), 500(HW), 501(HW)[c], 502(WW), 503(WW), 504(WW)[c], 505(CO), 506(CO)[c], 507(CP), 508(CP), 509(CP), 510(CP), 511(CP).

OCTOBER: 512(SM), 513(SM), 514(SM), 515(SM), 516(SM), 517(PO), 518(SM)[c], 519(IR), 520(IR), 521(IR), 522(IR)[c], 523(AT)[c], 524(SU), 525(SU)[c], 526(EM), 527(EM), 528(EM), 529(EM), 530(EM)[c], 531(EM), 532(EM)[c], 533(PO).

NOVEMBER: 534(HY), 535(HY), 536(HY), 537(HY), 538(HY)[c], 539(ST), 540(ST), 541(ST), 542(ST), 543(ST), 544(ST), 545(SA), 546(SA), 547(SA), 548(SM), 549(SM), 550(SM), 551(SM), 552(SA), 553(SM)[c], 554(SA), 555(SA), 556(SA), 557(SA).

DECEMBER: 558(ST), 559(ST), 560(ST), 561(ST), 562(ST), 563(ST)[c], 564(HY), 565(HY), 566(HY), 567(HY), 568(HY)[c], 569(SM), 570(SM), 571(SM), 572(SM)[c], 573(SM)[c], 574(SU), 575(SU), 576(SU), 577(SU), 578(HY), 579(ST), 580(SU), 581(SU), 582(Index).

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FEBRUARY: 608(WW), 609(WW), 610(WW), 611(WW), 612(WW), 613(WW), 614(WW), 615(WW), 616(WW), 617(IR), 618(IR), 619(IR), 620(IR), 621(IR)[c], 622(IR), 623(IR), 624(HY)[c], 625(HY), 626(HY), 627(HY), 628(HY), 629(HY), 630(HY), 631(HY), 632(CO), 633(CO).

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APRIL: 659(ST), 660(ST), 661(ST)[c], 662(ST), 663(ST), 664(ST)[c], 665(HY)[c], 666(HY), 667(HY), 668(HY), 669(HY), 670(EM), 671(EM), 672(EM), 673(EM), 674(EM), 675(EM), 676(EM), 677(EM), 678(HY).

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JUNE: 702(HW), 703(HW), 704(HW)[c], 705(IR), 706(IR), 707(IR), 708(IR), 709(HY)[c], 710(CP), 711(CP), 712(CP), 713(CP)[c], 714(HY), 715(HY), 716(HY), 717(HY), 718(SM)[c], 719(HY)[c], 720(AT), 721(AT), 722(SU), 723(WW), 724(WW), 725(WW), 726(WW)[c], 727(WW), 728(IR), 729(IR), 730(SU)[c], 731(SU).

JULY: 732(ST), 733(ST), 734(ST), 735(ST), 736(ST), 737(PO), 738(PO), 739(PO), 740(PO), 741(PO), 742(PO), 743(HY), 744(HY), 745(HY), 746(HY), 747(HY), 748(HY)[c], 749(SA), 750(SA), 751(SA), 752(SA)[c], 753(SM), 754(SM), 755(SM), 756(SM), 757(SM), 758(CO)[c], 759(SM)[c], 760(WW)[c].

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SEPTEMBER: 787(PO), 788(IR), 789(HY), 790(HY), 791(HY), 792(HY), 793(HY), 794(HY)[c], 795(EM), 796(EM), 797(EM), 798(EM), 799(EM)[c], 800(WW), 801(WW), 802(WW), 803(WW), 804(WW), 805(WW), 806(HY), 807(PO)[c], 808(IR)[c].

c. Discussion of several papers, grouped by Divisions.

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